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Physical Therapy Management for a Female Student Athlete Post-Concussion: A Case Report

By

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Abstract

Background and purpose: The purpose of this case report is to describe vestibular, oculomotor, and cervical interventions that were theorized to improve the function and decrease symptoms typically seen in the post-concussion population.

Case Description: The patient was a 16 year old female who was status post concussion due to head trauma during gymnastics routine. Symptoms included short term memory loss, fatigue, drowsiness, dizziness, difficulty concentrating, headaches, visual disturbances, and neck pain.

Outcomes: Patient was seen for 7 treatments over the course of 6 weeks which mainly focused on oculomotor training, vestibular training, and cervicogenic relief. Outcomes were consistent with the test and measures used to identify specific impairments.

Discussion: Interventions addressing oculomotor and vestibular dysfunction along with cervical involvement may be an effective treatment for patients post concussion.

Introduction

According to the Centers of Disease Control a concussion is defined as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head. Disturbance of brain function is related to neurometabolic dysfunction, rather than structural brain injury, and is typically associated with normal structural imaging findings. Concussion may or may not involve loss of consciousness. Concussion results in a constellation of physical, cognitive, emotional, and sleep-related symptoms. Recovery is a sequential process and symptoms may last several minutes to days, weeks, months, or even longer in some cases.”¹ There are many factors that are associated with a concussion that can be hard to identify and because of that, many physical therapists are reluctant to treat a concussion.

It is estimated that there are around 8 million people in the United States that acquire a concussion per year.² About 1.6 to 3.8 million individuals acquire their concussion from a sports-related incident.³ Approximately 9% of all high school sports injuries are concussions.⁴ Concussions usually present with cervicogenic properties, oculomotor disturbances, and/or vestibular impairments and when these interact with one another you can see a plethora of symptoms. Symptoms can include but are not limited to sleep alterations, fogginess, memory deficits, headaches, dizziness, visual impairments, and mood disruption.⁵ Due to the traumatic

nature of most concussions, neck pain is a common symptom due to strain put on the cervical spine and musculature. Another common side effect that can originate in the neck is a term called cervicogenic headaches or headaches originating from the cervical spine. According to the International Headache Society this specific type of headache will originate unilaterally in the back of the head and neck and will migrate to the front usually ending around the temporal region or behind the eyes.⁶

The vestibular system can be affected in concussion patients mostly due to the microstructural abnormalities from trauma that is a main contributor to dizziness.⁷ Dizziness is a frequent symptom of concussion and has been reported to occur in 23%-81% of cases in the first days after injury.⁸ The vestibulo ocular reflex (VOR) plays an important role in this system. The VOR is responsible for stabilizing vision while the head moves. Oculomotor control may also become an issue. Each eye sees its own image and the brain converges these images to make one clear image. If one eye isn't perfectly synchronized with the other, then we can see blurred vision due to different visual fields from the eyes.

The purpose of this case report is to explore different intervention options based off of the examination findings for a post-concussion female athlete. This case report is meant to be informative as a basis of prescribing a rehabilitation exercise program for patients with concussion on how to

better understand treatment based off of examination findings of common concussion symptoms.

Subject

The patient used for this case report was a 16 year old female high school student who participates in gymnastics for a club team. During practice, she reported falling backwards and hitting her head on the mat during a routine. She reported a loss of consciousness lasting approximately 5 second however she did not report any symptoms at this time. She did not receive medical treatment at the time of the incident. She has a history of concussions stating that this is her fourth concussion. She has received physical therapy in the past for her concussions that reportedly helped with her symptoms. She reported that with this particular concussion she was experiencing short term memory loss, fatigue, drowsiness, difficulty concentrating, headaches (5 per week), and visual disturbances. She also reported experiencing neck pain and dysguesia, which is an occasional metallic taste in her mouth, with cervical extension.

She also was recently diagnosed with migraines, which runs in the family. This co morbidity is important to note because this is a vascular disorder effecting vessels in the brain which could affect treatment for a concussion. Per patient report, neurology consult was clear along with normal MRI, X-ray, and CT scans of the brain and neck. Having experience with concussions, she thought the symptoms would get better on their own

but 4 weeks post-concussion the symptoms persisted and she sought out physical therapy for further evaluation. Her goals for physical therapy were to address the above symptoms so that she could focus on school and gymnastics again.

Clinical Impression #1

Based off of the history given by the patient, most of her symptoms were concurrent with that of a concussion. Examination was focused on specific visual, vestibular, and musculoskeletal impairments. These three systems work together to keep your brain in a homeostatic state and if one or more of these systems is effected, it can have a snowball effect on the others. With most concussions, visual disturbances occur due to an asynchronization between the eyes causing blurred vision, difficulty concentrating, and increase in fatigue due to extra processing the brain must do. It is important to test saccadic function, smooth pursuit, and convergence to diagnose the exact cause of the visual disturbance reported by the patient. Due to the connection between the vestibular system and the oculomotor system it was important to identify any impairment that could be lingering in either of the systems. Due to the traumatic nature of the patient's concussion it was also important to address any movement limitations in the cervical spine.

Test and Measures

Palpation/Joint Mobility

The patient was complaining of neck pain indicating a priority to palpate cervical spine musculature. Patient was lying prone while therapist palpated posterior neck musculature. Joint mobilization consisted of applying direct posterior to anterior pressure to spinous process of the cervical spine. Thoracic mobility consisted of applying posterior to anterior pressure on the transverse processes.

Range of Motion

During initial evaluation, the patient's cervical range of motion was measured with a standard goniometer and standard inclinometer. All measurements were taken with the patient seated. For cervical flexion and extension, the inclinometer was placed on top of the patient's head aligned with the external auditory meatus in the sagittal plane and then zero'ed. For cervical side bending, the inclinometer was placed in the frontal plane on top of the patient's head in alignment with the external auditory meatus and then zero'ed. For a single inclinometer use Hoving et al reports reliability ranging from .93 to .97.⁹ For cervical rotation, the standard goniometer is used with the fulcrum placed over top of head with the stationary arm aligned with the acromion process, and the moveable arm bisecting the patient's nose. The reliability for using a goniometer for cervical rotation is

described by Youdas et al to be .97.⁹ These measurements were repeated at the re-evaluation occurring six weeks after initial evaluation.

Oculomotor Examination

Tracking/Smooth pursuit

The patient was sitting with the therapist standing approximately two feet away at patient's eye level. The patient was asked to keep the head and neck stationary and only move their eyes. The therapist held a finger and asked the patient to follow the finger. The motion of the therapist should follow an "H" pattern going to end range of patient's ocular ability. Therapist should be observing patient's eyes throughout entire test and is looking for symmetry between both eye movements.

Saccadic Function

The patient was sitting with the therapist standing approximately two feet away at patient's eye level. The patient was asked to keep the head and neck stationary and only move their eyes. The therapist holds up a finger at the patient's end range of ocular movement in the coronal and horizontal planes. Therapist holds finger at end range and asks patient to transition between therapist's finger and therapist's nose. The therapist should be observing patient's eyes throughout entire test and is looking for quick, smooth eye movements. For example, a hypometric saccadic function means

that the eyes make jerky, slow movements to look at objects. When looking from one object to the next, there should be a smooth eye transition without any abnormal tracking.

Convergence

The patient was sitting with the therapist standing approximately two feet away at patient's eye level. The patient was asked to keep the head and neck stationary and only move their eyes. The therapist will begin to bring in the target towards the patient's nose. The patient is asked to follow the finger and report when the target becomes blurry or when double vision occurs. The therapist should be observing eye movement throughout the entire test to make sure that both eyes are converging properly on the target. Abnormalities can include a delay of medial movement of the eyes or hypoconvergence. This can affect the patients overall vision due to a lack of symmetry between the eyes causing blurriness or even dizziness.

Near point Convergence

When the patient reports blurriness or diplopia (double vision) during the convergence test, the therapist stops bringing the target towards the patient and a measurement is taken in centimeters of the distance between the patient's nose and finger. A non-symptomatic individual has a convergence distance of 6 cm before diplopia occurs.¹⁰

Cover/Uncover Test

Patient was seated looking straight ahead. The patient was asked to keep both eyes open while the therapist covers one eye so that the patient cannot see anything out of that eye. The patch is held there for 5 seconds then quickly removed. The therapist should observe any eye movement when the eye becomes uncovered. Abnormal findings include an exotropia or esotropia of a single eye or both eyes. This can be described as the eyes deviating outward or drifting inward respectively.

Vestibular Examination

Vestibular-Ocular Reflex (VOR) Test

Patient is asked to actively move head in the coronal plane and in the horizontal plane while keeping their eyes fixed directly in front of them. The patient should move their head at least 20 times in each direction. They are instructed to move as fast as they feel comfortable while keeping object in focus. The therapist stands in front of patient and can use the therapist's nose as a target by the patient. The therapist should be observing the speed of the head motion along with any increase of symptoms by the patient. The purpose of this reflex is to maintain focus on an object with the eyes while the head is in motion.

VOR Repetition

The Patient was asked to actively move their head in the coronal and sagittal planes while keeping their eyes fixed directly in front of them. The patient is asked to move their head as fast as they feel comfortable while keeping the object in focus. A frequency rate of the revolutions is then recorded. In non-symptomatic patients, the average speed is 100 repetitions/minute.

Head Thrust Test

The patient was seated in a chair with the therapist standing in front of patient. Therapist puts their hands on either side of the patient's head and was asked to focus on the therapist's nose throughout the test. The therapist flexes the head 30 degrees and performs several slow passive rotations to reduce cervical tone. The therapist then applied a quick rotational force to the head for about 5-10 degrees. Therapist should look for any corrective movement made by the patient's eyes. According to Lei-Rivera et al the test has low sensitivity and high specificity except in cases of significant impairment.¹¹

Optokinetic Reflex

The patient is in a seated position looking straight ahead. The therapist holds a standard optokinetic tape and passes it past patient's eyes; first,

from left to right, and then right to left. Therapist should observe smoothness of eyes, fatigability, and the direction of the eyes.¹²

Fukuda's Step Test

The Patient is standing with shoulders flexed to 90 degrees. Patient is instructed to close their eyes and march in place 50 times. The therapist should be observing for any rotation or turning by the patient during the marches. Therapist should measure the angle of rotation; a negative test means the patient was able to march in place without turning or rotating. A degree of less than 30 is indicative of ruling out a asymmetric labyrinth dysfunction.¹³

Computerized Dynamic Visual Acuity Test (CDVAT)

The patient is seated with a laptop set 2 meters away at eye level. A Microsoft PowerPoint program was used to present the stimuli.¹⁴ The stimuli consisted of a string of 5 white numbers on a black background. Each of the 5 numbers was from the set 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9. Patient was asked to voluntarily move head in a vertical pattern at a constant rate of 2.0 Hz.¹⁴ The computer program has head rotation time synchronized to an auditory cue. The first round is stationary head, the second is vertical head rotation, and the third is horizontal head rotation. The therapist is looking for signs of oscillopsia, or eye movements in which the eyes oscillate.

Re-Evaluation

This took place six weeks after the initial evaluation. The patient returned from vacation and gymnastics camp to continue therapy. She reported an approximate 65% improvement in symptoms of headaches and dizziness since initial treatment. She continues to experience headaches following increased stress and reading. The headaches have mainly been specified to the left side. She also reported improvement of dysguesia. Other improvements include cervical extension range of motion, saccadic function, near point convergence, and VOR repetition. However, after further evaluation by the therapist, a temporomandibular joint (TMJ) dysfunction was found. The patient had noted tenderness in the bilateral temporalis muscles and left medial and lateral pterygoids. The patient's TMJ range of motion was normal with the exception of right lateral deviation which was limited by 50%. The patient was instructed to eat softer foods and discontinue any gum chewing. The patient was given a home exercise program for controlled TMJ depression.

Diagnosis and Prognosis

Based off of the initial evaluation findings, we have determined that the patient had specific neuromuscular impairments including decreased oculomotor coordination, decreased vestibular function, decrease in cervical range of motion, decrease in spinal segmental mobility, and decreased soft

tissue mobility. These limitations have most likely stemmed from her concussion limiting her ability to participate in activities of daily living. Such limitations include reading, paying attention during class, and fatigue/drowsiness attributing to her poor activity tolerance. These limitations have directly affected her occupation as a high school student and as a competitive gymnast. The patient's prognosis was based off of the findings from the initial evaluation, the age of the patient, previous number of concussions, other co morbidities that could affect treatment (ie. Migraines), and the physical therapist's clinical expertise regarding concussion. Given the correct rehabilitation program which includes, but is not limited to, oculomotor training, vestibular therapy, and manual therapy, the patient would meet all goals and return to school, recreational activities, and ADL's symptom free within 8 weeks. Most patients showing these types of symptoms 4 weeks post concussion are symptom-free 12-16 weeks post concussion.¹⁵

Intervention

Patient Education

Patient was informed about the physiology of a concussion. Patient was educated on how her symptoms correlated to the concussion. She was also told to keep a headache log to monitor the amount of times per week she was getting headaches and what she was doing that brought about the

headache. She was also educated on proper posture to decrease her forward head and rounded shoulders. At re-evaluation, patient was also educated on TMJ pathology and symptom management strategies including; decrease gum chewing and a home exercise program of controlled mandibular depression.

Stretching

Due to the examination findings of restricted movement in the cervical extrinsic muscles and the forward shoulder posture, stretching is a key component in addressing these limitations. Patient was required to lay on a foam roll with arms overhead at about 90-120 degrees of shoulder abduction. Patient was asked to lie in this position for 5 minutes. This exercise is statically stretching the pectoralis major/minor.

Another stretching exercise consisted of the patient lying supine and the therapist hold the head of the patient. Passive stretch was given by the therapist by side bending the patients head. Therapist would hold this for 15 seconds and repeat 3 times in each direction. This exercise statically stretches the upper trapezius. The therapist would then rotate head laterally to stretch the sternocleidomastoid muscle.

The final stretch done was a passive suboccipital release. The patient was lying in supine with the therapist's hands positioned under the head. The pads of the therapist's fingers should be located on the suboccipital

muscle belly just inferior to the superior nuchal line.¹⁶ The therapist provides a pull in a caudalcephalic manner. This pull should be held for 4 minutes to provide release to the suboccipital muscles.

Joint Mobilization

The patient demonstrated joint limitations in the C2-3 spine and also at the midthoracic spine. Grade III joint mobilization was applied to the patient lying in supine with the neck in a neutral position, with the therapist's fingers applying an upward force on the spinous process of C2 and C3.¹⁶ Grade III joint mobilization was applied to T3-6. Patient was lying in prone with the therapist's index finger and middle finger on each end of the transverse processes. Therapist applied an anterior glide into the table. Grade V joint mobilization was applied to the midthoracic spine. An article by Cleland et al. showed a positive correlation between the use of midthoracic manipulation as having positive effects on neck pain.¹⁸ Patient was lying prone with the therapist's hypothenar eminence of each hand over the transverse processes. The therapist applies a slight rotational force to pick up slack in the fascia and muscles followed by an anterior thrust into the table.

Soft Tissue Mobilization

The patient was lying in prone so that the therapist had access to back/neck musculature. The therapist used a cross-fiber, friction massage to the bilateral upper trapezius, bilateral levator scapulae, and bilateral rhomboids. The therapist would identify any trigger points in the musculature and release the adhesions/restrictions.

Oculomotor Training

This exercise involved optokinetic training. The therapist taped a 2 inch diameter circle to the track of a treadmill. The patient was standing over the treadmill and was asked to constantly look at the circle. The therapist set the treadmill at 2 MPH. This was done for 5 minutes.

Saccadic Exercises

The first exercise was called saccadic clocks which involved the therapist labeling a mirror with a dry erase marker at patient eye level with the numbers 1-4 in a plus sign fashion. The patient stands 2 feet away from the mirror as the therapist shouts out numbers 1-4 at a speed of about 1 number/second. This will indicate which number the patient should look at. The patient did 3 sets of this for 30 seconds each set.

The second exercise was called saccadic swing Hart chart which involved a standard Hart chart placed on a wall at patient's eye level. Patient would stand roughly 8 feet from the chart and read one row at a time. However, each row should be read in a way where the patient begins from

the first letter, then the last letter, back to the second letter, then to the second to last letter and so on. This is very important because this makes the eyes jump from one letter to the next instead of reading them right down the line. This was done once until the patient could read through the entire chart.

Convergence Exercises

The first exercise involved a standard Brock String. This is a 6 foot long string with the first bead (green) being placed 14 inches from the patient's nose, the second bead (yellow) being placed 30 inches from patient's nose, and the last bead (red) being placed 5 feet from patient's nose.¹⁷ The string is attached to an object that is at patient's eye level. The patient holds the other end of the string up to their nose. The therapist will ask the patient to stare at the green bead and report how many beads they see. The patient should see two yellow and two red beads. Once the patient can focus on that you move to the yellow bead. The patient should see two red beads and two green beads once they focus. Finally, the patient looks at the red bead and should see two green beads and two yellow beads. Have the patient repeat this for 2 sets of 10 times each set.

The second exercise involves a two standard Hart charts. One placed on the wall at patient's eye level and the other is held 1 foot in front of the patient. The patient is asked to read the first line on the close chart then

jump to the far chart and read the first line. Followed by the patient reading the second line in the row on the close chart then look at the far chart and read the second line. The patient will continue to do this for the entire chart.

Thermotherapy

The patient would require a cervical hot pack applied to the cervical extensors while the patient was lying in supine for 10 minutes. The purpose of this was to warm up the muscles and also provide a calming effect to the patient.

Vestibular exercises

These types of exercises involved a lot of head turns with typical therapeutic exercises. The patient was asked to hold a plank for 30 seconds and during this exercise, the patient is to turn their head side to side. Another exercise was during dynamic hamstring stretching. The patient was asked to balance on one leg and lean forward with trunk and upper body until a pull was felt in the grounded back of leg. Patient would switch legs and repeat 10 times on each leg. Patient was asked to turn head side to side throughout entire exercise.

Another vestibular exercise focused on gaze stabilization. The patient was asked to sit on a 55cm exercise ball that was positioned 2 feet away from a mirror. The therapist placed an "X" on the mirror with a dry erase

marker at the patient's eye level. The patient was asked to bounce up and down on the exercises ball while never taking their eyes off of the "X". The patient did 4 sets for 30 seconds each set.

Visit #	Int 1	Int 2	Int 3	Int 4	Int 5	Int 6	Int 7	Int 8	Int 9
1 (Eval)	X								
2	X	X	X	X	X	X			
3		X	X	X	X	X		X	X
4		X	X	X	X	X		X	
5		X	X	X	X	X			
6	X	X	X	X				X	X
7(Re-Eval)	X	X	X	X			X	X	

Table 4 - Interventions

1= Patient Education	6 = Convergence Exercises
2 = Stretching	7 = Thermotherapy
3 = Joint Mobilization	8 = Vestibular Exercises
4 = Soft Tissue Mobilization	9 = Gaze Stabilization Exercises
5 = Saccadic Exercises	

Outcomes

The patient attended 2 visits per week for the first 3 weeks before unexpectedly leaving for 2 weeks for a vacation and a gymnastics camp. Patient was seen once following her unexpected hiatus before data collection was discontinued. However, the patient continued physical therapy with regular staff therapist and the proceeding data was not available to be included in this study.

Palpation/Joint Mobility

Patient had several trigger points noted in the bilateral upper trapezius, rhomboids, suboccipital muscles, and levator scapulae. Patient also had poor mobility at the levels of C2-3 and pain and tenderness noted at T4.

Cervical AROM	Initial Evaluation	Re-Evaluation
Flexion	0-50°	0-50°
Extension	0-35°	0-50°
Right Side bend	0-45°	0-45°
Left Side bend	0-45°	0-45°
Right Rotation	0-70°	0-70°
Left Rotation	0-70°	0-70°

Table 1 – Cervical Active Range of Motion

	Initial Evaluation	Re-Evaluation
Tracking/Smooth Pursuit	WNL	WNL
Saccadic Function	Hypometric all planes	Hypometric Laterally
Convergence	Hypoconvergence on Right	Hypoconvergence on Right
Near Point Convergence	16 cm	9 cm
Cover/Uncover Test	Right eye Exophoria	Right eye Exophoria

Table 2 – Oculomotor Examination

	Initial Evaluation	Re-Evaluation
Vestibulo-Ocular Reflex (VOR)	Slow & Symptomatic	Slow & Symptomatic
VOR repetition	Unable to tolerate	75
Optokinetic Reflex	Poor	Poor
Head Thrust Test	Negative	Negative
Fukuda's Step Test	20 degrees right rotation	Negative
Computerized	Unable to tolerate	100%

Dynamic Visual Acuity Test (CDVAT)		
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Table 3 – Vestibular Examination

Discussion

90% of concussions get better on their own within 4 weeks.¹⁹ When symptoms continue, it is important to seek treatment to address these issues. With an increase in high school-related concussions each year, it is important to address physical therapy interventions that will assist in the healing process. The purpose of this case report was to explain common tests done for a post-concussion patient and possible treatment options on how to address the limitations.

The patient showed a 65% decrease in frequency of headaches since initial evaluation. This is an important outcome because the number 1 symptom of post-concussion athletes is headaches, which occurs in 75% of high school athletes.¹⁵ The patient also showed improvement in cervical extension by 15 degrees. This is important to note because extension caused an increase of symptoms. Other notable improvements were near-point convergence, fukuda's Step Test, and saccadic function. It can be hypothesized that the interventions used for this patient may have had a positive effect on her concussion symptoms.

Some limitations to the study were the two week absence of the patient. Although the patient did show improvement at re-evaluation, there

is a two week gap between treatment and re-evaluation. Also, a lack of psychometric data limits the reliability and validity of many of the test and measures.

Due to the plethora of symptoms typically seen in concussions, future studies should focus on a more holistic treatment approach; focusing on all treatment options including oculomotor, vestibular, and cervical. There are many studies that focus on only vestibular exercises or only vergence exercises but there is little research done on treating all impairments together.

References

1. Alsalaheen B, Whitney S, Mucha A, Morris L, Furman J, Sparto P. Exercise Prescription Patterns in Patients Treated with Vestibular Rehabilitation After Concussion. *Physiotherapy Research International* [serial online]. June 2013;18(2):100-108.
2. Thiagarajan P, Ciuffreda K, Ludlam D. Vergence dysfunction in mild traumatic brain injury (mTBI): a review. *Ophthalmic & Physiological Optics* [serial online]. September 2011;31(5):456-468.
3. Giza CC, Kutcher JS, Ashwal S, et al. Summary of evidence-based guideline update: evaluation and management of concussion in sports: report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology*. 2013;80(24):2250-7.

4. Meehan W, d'Hemecourt P, Dawn Comstock R. High School Concussions in the 2008-2009 Academic Year. *American Journal Of Sports Medicine* [serial online]. December 2010;38(12):2405-2409.
5. Lovell M, Iverson G, Maroon J, et al. Measurement of Symptoms Following Sports-Related Concussion: Reliability and Normative Data for the Post-Concussion Scale. *Applied Neuropsychology* [serial online]. September 2006;13(3):166-174.
6. Available at: http://ihs-classification.org/en/02_klassifikation/03_teil2/11.02.01_cranial.html. Accessed November 11, 2014.
7. Fife T, Giza C. Posttraumatic Vertigo and Dizziness. *Seminars In Neurology* [serial online]. July 2013;33(3):238-243.
8. Alsalaheen BA, Mucha A, Morris LO, et al. Vestibular rehabilitation for dizziness and balance disorders after concussion. *J Neurol Phys Ther*. 2010;34(2):87-93.
9. Reese NB, Bandy WD. Joint Range of Motion and Muscle Length Testing. Elsevier Health Sciences; 2009.
10. Scheiman M. The Convergence Insufficiency Treatment Trial: Design, Methods, and Baseline Data. *Ophthalmic Epidemiology* [serial online]. January 2008;15(1):24-36.
11. Lei-rivera L, Sutera J, Galatioto JA, Hujsak BD, Gurley JM. Special tools for the assessment of balance and dizziness in individuals with mild traumatic brain injury. *NeuroRehabilitation*. 2013;32(3):463-72.

12. Available at: <http://opkflag.com/instructions>. Accessed November 12, 2014.
13. Fukuda, T. (1959). "The stepping test: two phases of the labyrinthine reflex." *Acta Otolaryngol* 50(2): 95-108
14. Roberts R, Gans R, Johnson E, Chisolm T. Computerized Dynamic Visual Acuity With Volitional Head Movement in Patients With Vestibular Dysfunction. *Annals Of Otology, Rhinology & Laryngology* [serial online]. September 2006;115(9):658-666.
15. Kontos A, Elbin R, Collins M, et al. A Revised Factor Structure for the Post-Concussion Symptom Scale: Baseline and Postconcussion Factors. *American Journal Of Sports Medicine*[serial online]. October 2012;40(10):2375-2384.
16. Kisner C, Colby LA. *Therapeutic Exercise, Foundations and Techniques*. F.A. Davis; 2012.
17. Available at: <http://www.yourfamilyclinic.com/ND/vision/brock.html>. Accessed November 11, 2014.
18. Cleland J, Mintken P, Hancock M, et al. Examination of a Clinical Prediction Rule to Identify Patients With Neck Pain Likely to Benefit From Thoracic Spine Thrust Manipulation and a General Cervical Range of Motion Exercise: Multi-Center Randomized Clinical Trial. *Physical Therapy* [serial online]. September 2010;90(9):1239-1253.
19. Lovell M, Iverson G, Maroon J, et al. Measurement of Symptoms Following Sports-Related Concussion: Reliability and Normative Data for the Post-

Concussion Scale. *Applied Neuropsychology*[serial online]. September 2006;13(3):166-174.